DARPA STAB Kickoff Meeting:

Liquid Crystal Agile Beam Steering

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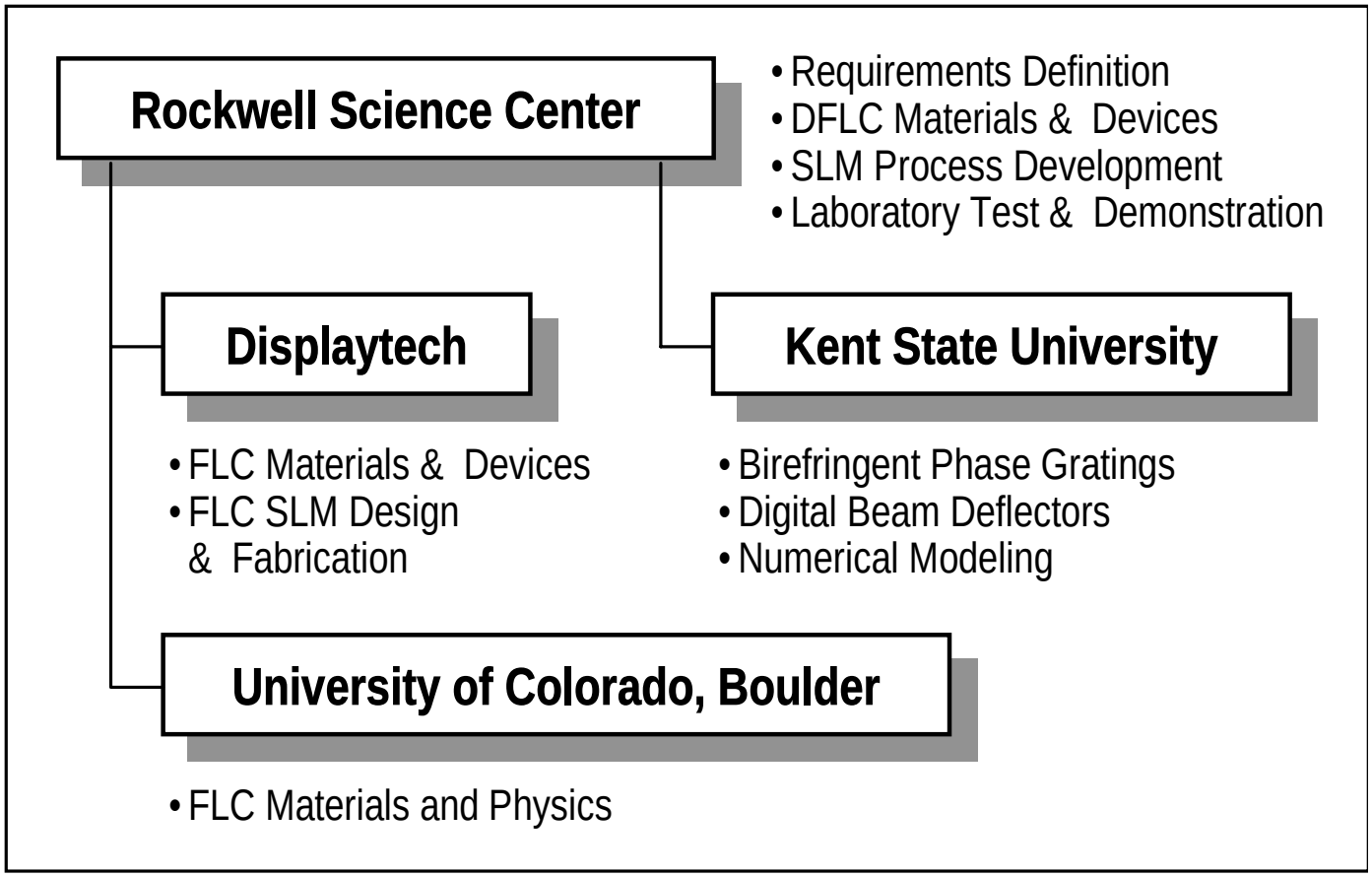
RSC Liquid Crystal Agile Beam Steering Program

- **Applications: Laser Comm and Target Designation**
- **3 year baseline program: $2.4M**
- **4th year options: $682K**



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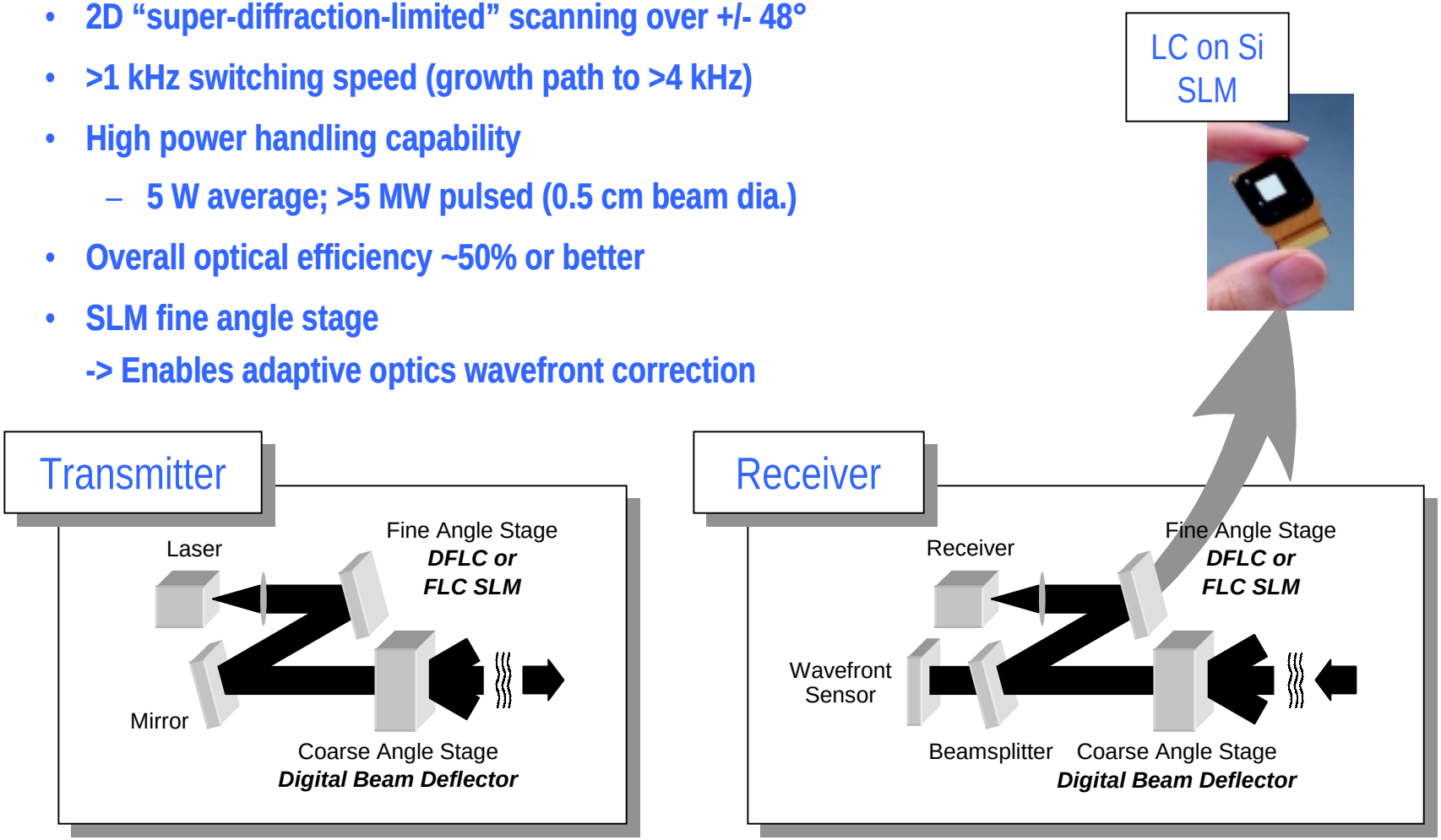
Liquid Crystal Agile Beam Steering (LCABS) Architecture

- No moving parts / scalable technology
- Random access multiple target addressing
- 2D "super-diffraction-limited" scanning over +/- 48°
- >1 kHz switching speed (growth path to >4 kHz)
- High power handling capability
  - 5 W average; >5 MW pulsed (0.5 cm beam dia.)
- Overall optical efficiency ~50% or better
- SLM fine angle stage

  -> Enables adaptive optics wavefront correction



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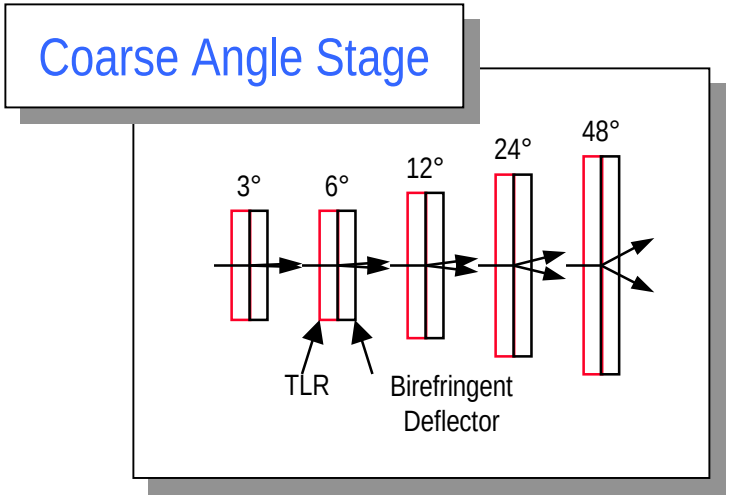
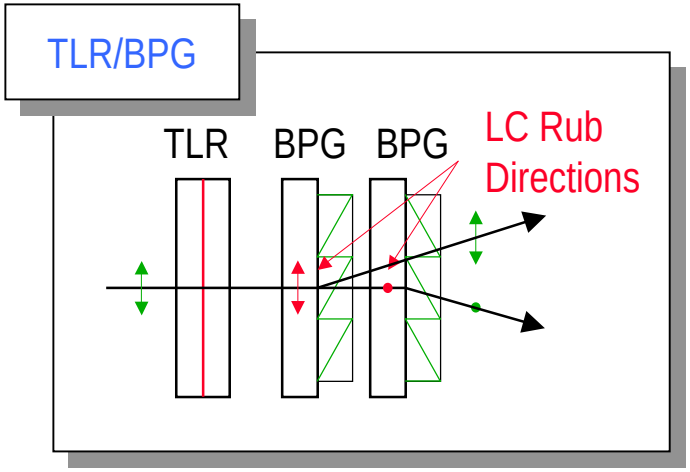
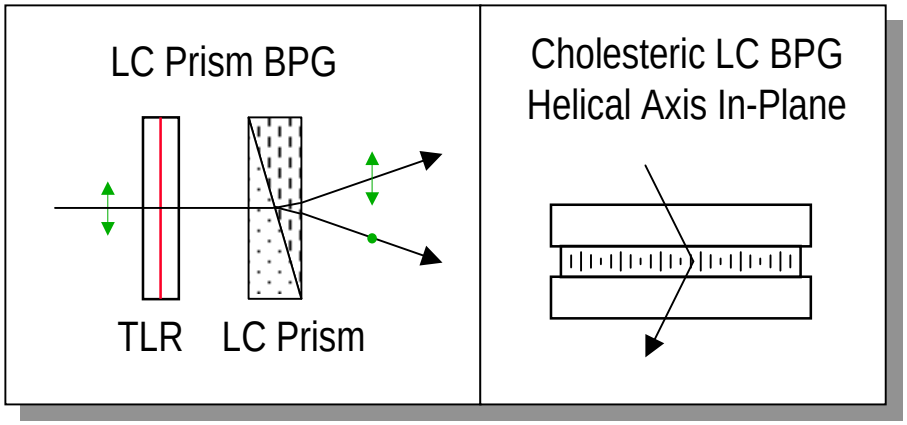
Coarse Angle Beam Steering

- λ/2 Tunable LC Retarder (λ/2 TLR)
  - Dual frequency LC tunable waveplate
  - 2 kHz demonstrated @ λ=1.55 μm
  - High efficiency transparent electrode
- Birefringent phase grating (BPG)
  - Photopatterned birefringent thin film
  - LC Prism / Cholesteric LC thin film
  - Phase grating profile optimized by finite difference time domain modeling
- Multiple stages -> Optical efficiency challenge







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Statement of Work Summary

	Schedule (MO)
• **Baseline Program**	
– 1D Fine Angle Steering	1-36
• Feasibility Assessement	
• Prototype Development	
• Optical Test and Evaluation	
– 1D Coarse Angle Steering	1-36
• Feasibility Demonstration	
• Prototype Development	
• Portable 1D Digital Beam Deflector	
• Optical Test and Evaluation	
• **Option 1: 2D Fine Angle Steering**	37-48
– Wavefront Control SLM	
– Optical Test and Demonstration	
• **Option 2: 2D Coarse Angle Steering**	37-48
– 2D Digital Beam Deflector	
– Optical Test and Demonstration	

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Baseline Program Deliverables

	Schedule (MO)
Phase I:	
• Reports	12
– Component Models and Optical Test Equipment	
– Preliminary Optical Design	
– Analog FLC Feasibility Assessment	
– Digital Beam Deflector Feasibility Assessment	
Phase II:	
• Demonstrations	18
– 1-pixel Analog FLC Modulator	
– DFLC Beam Steering Device	
– Custom Controller for 1D Beam Steering Devices	
– Digital Beam Deflector Components	

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Baseline Program Deliverables Cont'd

	Schedule (MO)
Phase II:	
• Demonstrations (enhanced performance)	24
– 1-pixel Analog FLC Modulator	
– DFLC Beam Steering Device	
– 1D Super-Diffraction-Limited Beam Steering	
– Digital Beam Deflector Components	
• Demonstrations	30
– 1D FLC Beam Steering Device	
– 1D Super-Diffraction-Limited Beam Steering	
– 1D Digital Beam Deflector	
• Deliverables	36
– Detailed Design for Portable 2D Beam Steering Demo Unit	
– Integrated 1D Beam Steering Demo Unit	

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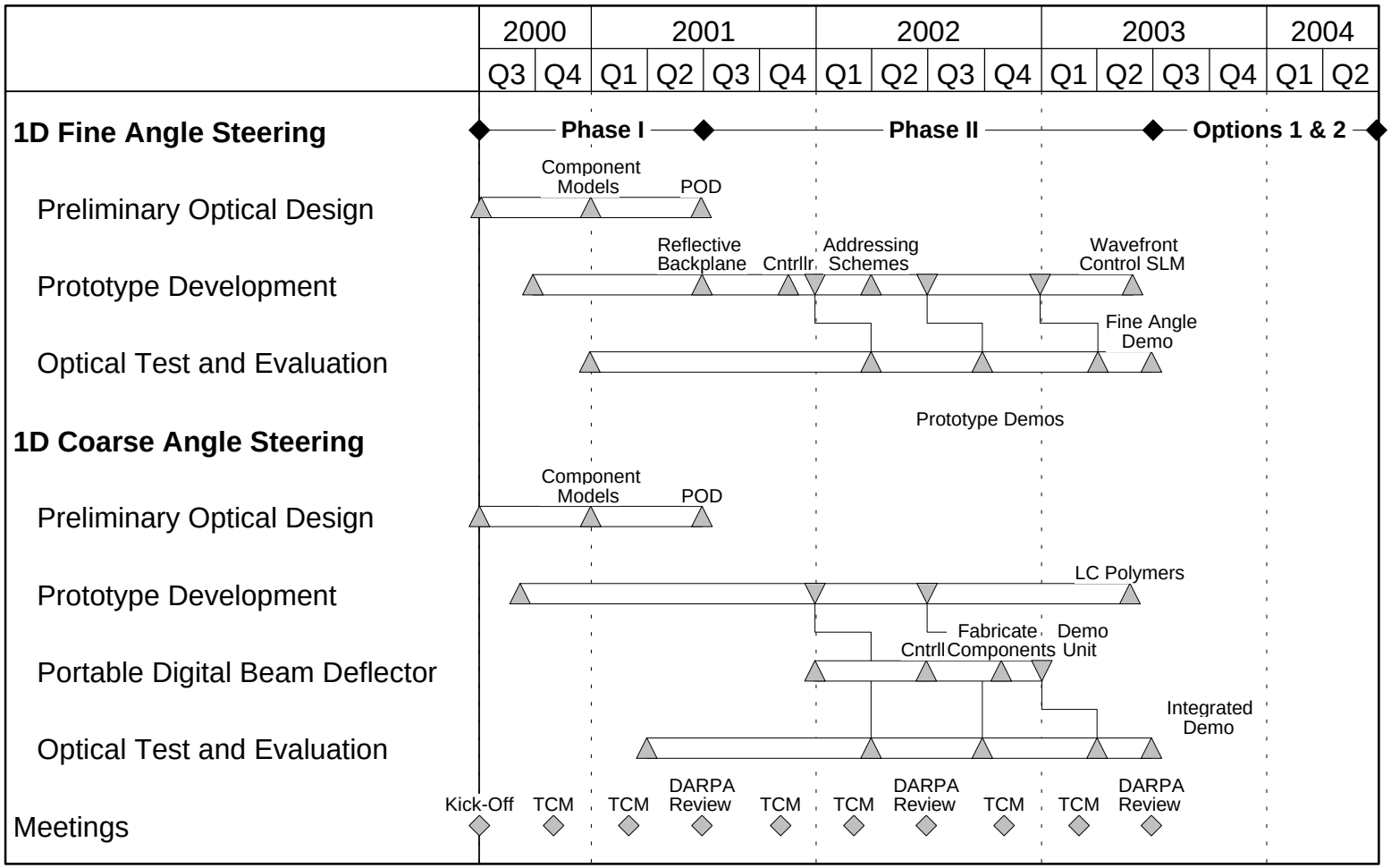
RSC LC STAB Program Schedule

Baseline Program

Baseline Program: 1D Agile Beam Steering



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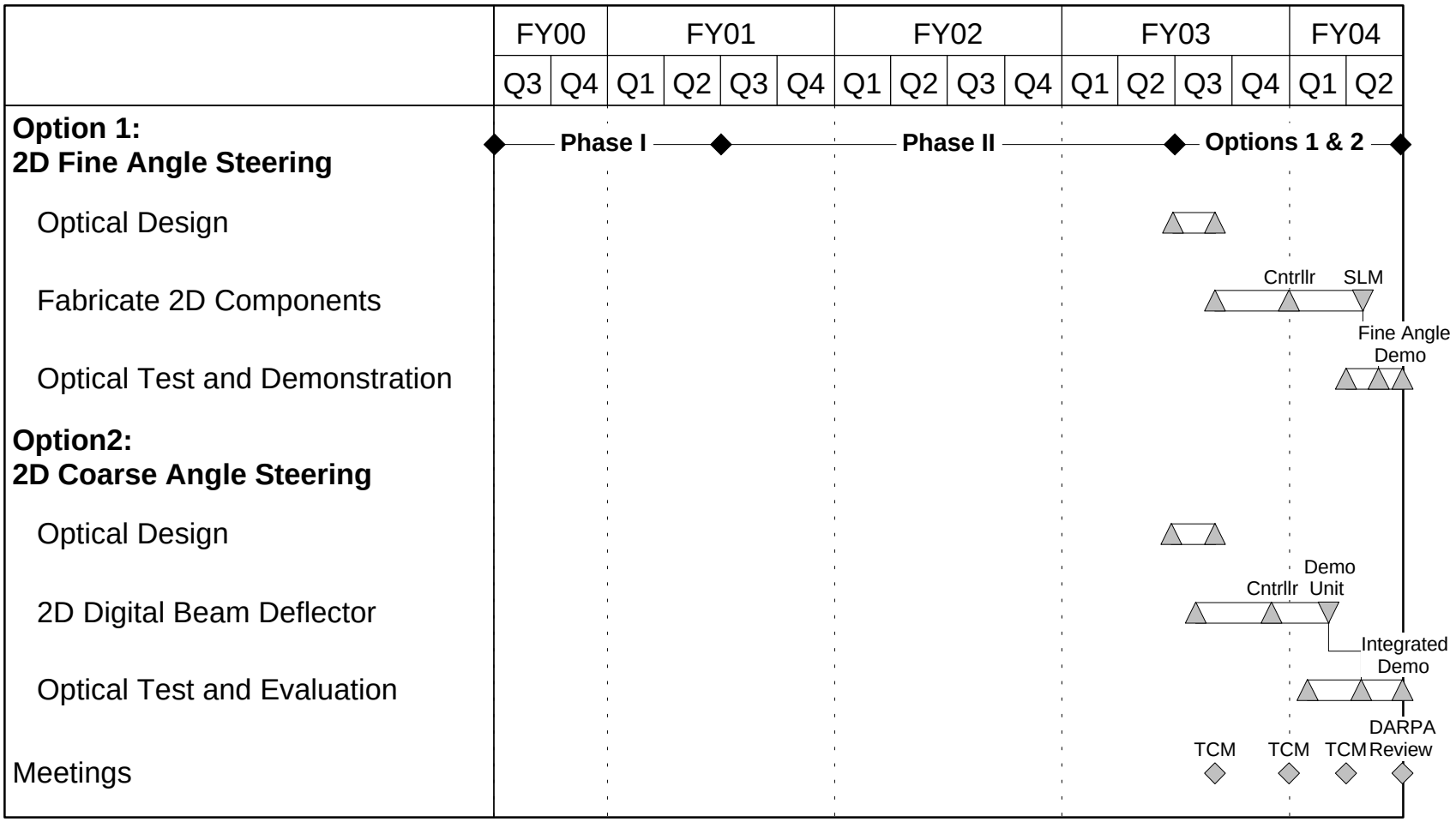
RSC LC STAB Program Schedule
Options

2D Agile Beam Steering Options



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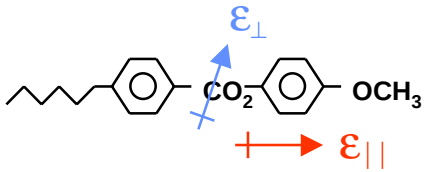
Switching Speed of Nematic Liquid Crystals

- **Dielectric Anisotropy**
  - Induced dipole:



$\Delta\varepsilon = \varepsilon_{||} - \varepsilon_{\perp} > 0$ E↑

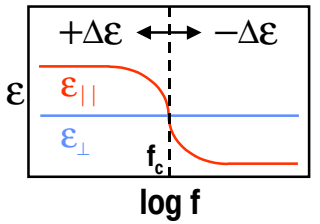
$\Delta\varepsilon < 0$ E↑

- **Common Fast Electrooptic Modes:**
  - Electrically controlled birefringence (ECB)
    - Relaxation slow due to backflow
  - pi cell
    - Metastable pi state
    - No backflow, but relaxation rate still limited due to weak elastic forces working against viscosity
    - ~200 Hz modulation rate considered "fast"

ECB: Field ON → (Fast) Field OFF → (Slow Relaxation)

pi cell: Low V ON → (Slow) High V ON → (Fast) Low V ON → (Relax)

- **Dual Frequency Liquid Crystals (DFLC)**
  - Parallel dielectric coefficient is highly dispersive
  - $\Delta\varepsilon$ changes sign at crossover frequency (1-40 kHz)
  - Relaxation can be field driven: 0.50 ms in either direction ($\lambda/2$ @ 1.5 μm in transmission)
  - Analog modulation requires 1°C temperature stabilization



Low f ON → (Fast) High f ON → (Fast)

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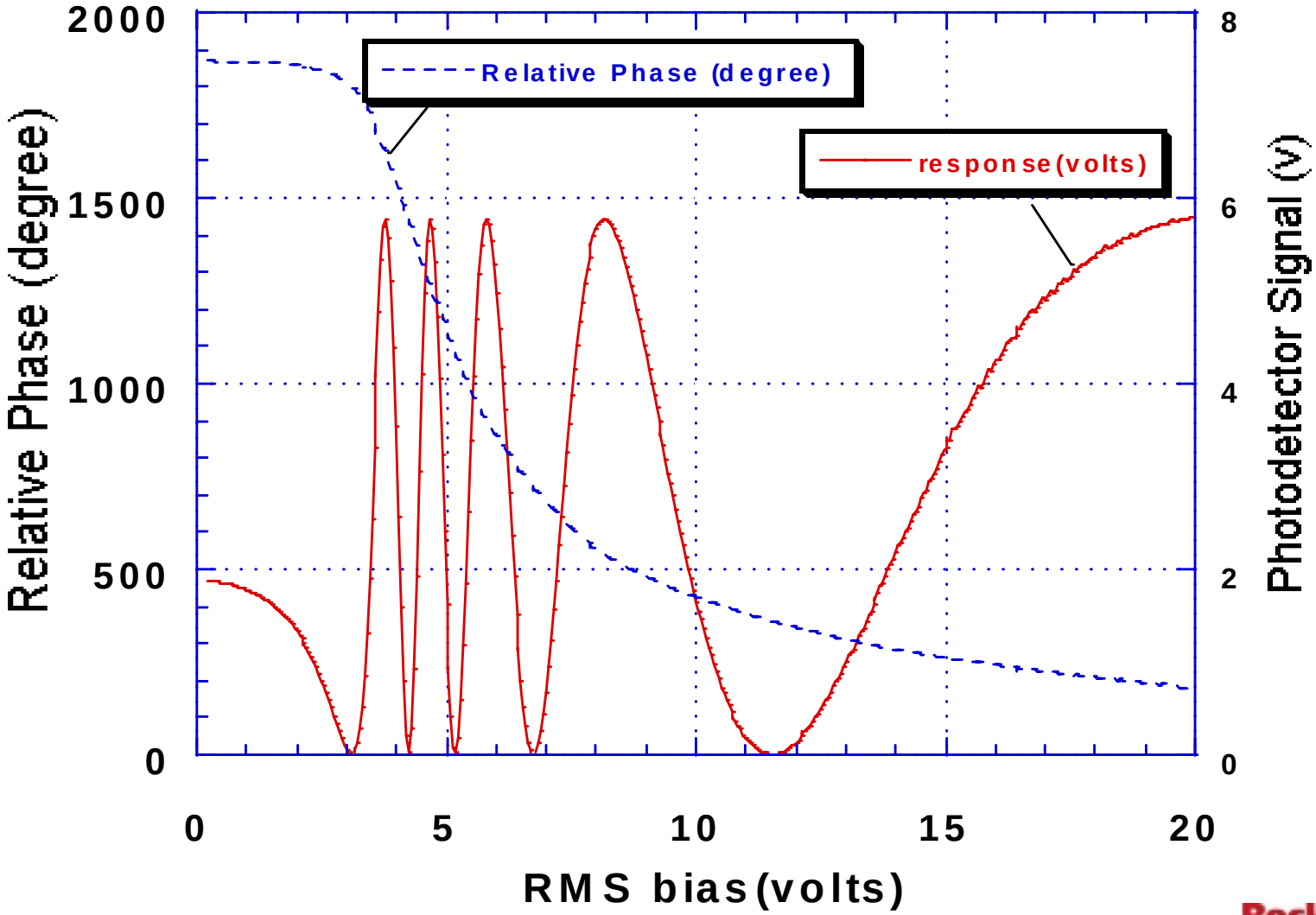
DFLC Phase Modulation

Electrooptic Response

$$I(v) = I_0 * \mathrm{Sin}^2[\Phi(v)/2]$$



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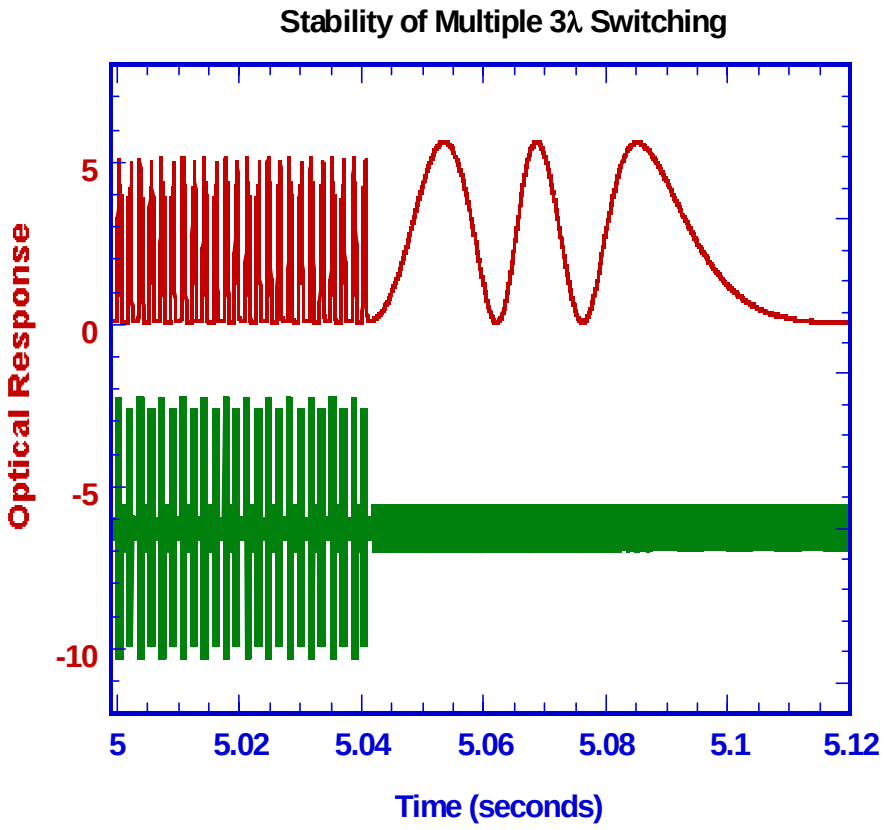
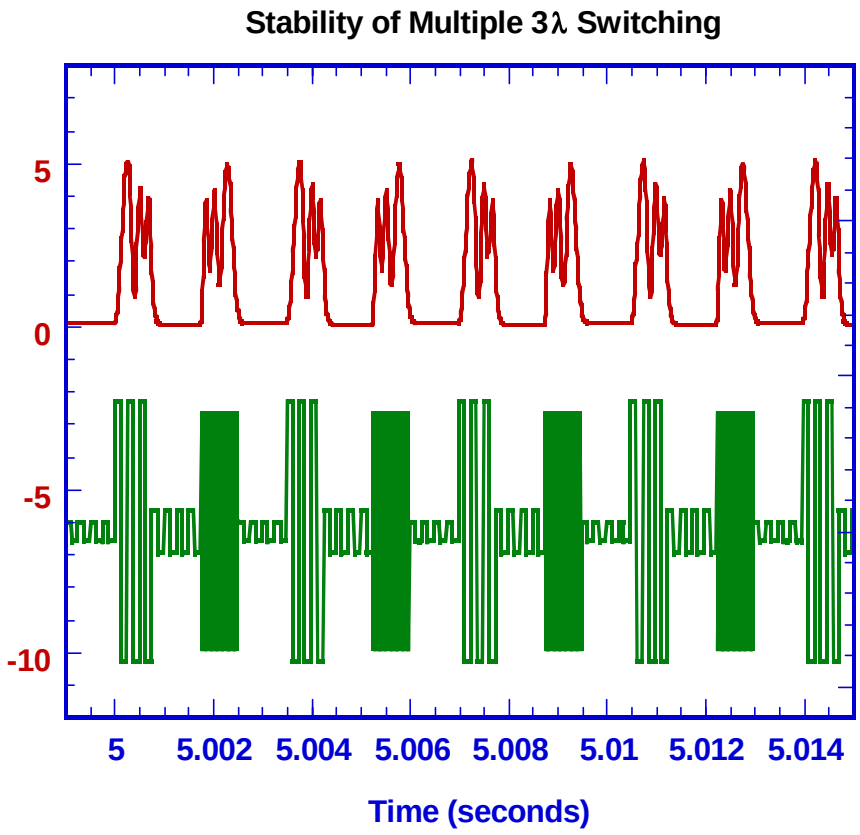
DFLC Phase Modulation

Reproducibility





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